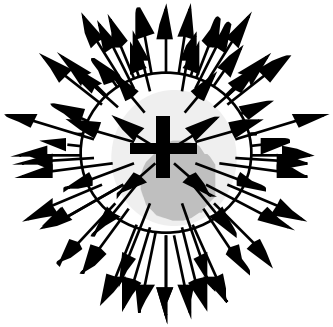
What's on the menu?

- Introduction to electric & magnetic fields
  - Electric fields
  - Magnetic fields
  - Electromagnetic radiation
  - Near fields & far fields
- Radiofrequency/microwave radiation and fields (rfmw)
  - Concepts and introduction to rfmw
  - Reminders and terminology
  - Rfmw energy transfer to tissue/dosimetry
  - Rfmw biological effects
  - Rfmw standards
  - Microwave ovens
  - Controlling exposures to rfmw
- Steady (dc) magnetic fields

Introduction to electric & magnetic fields

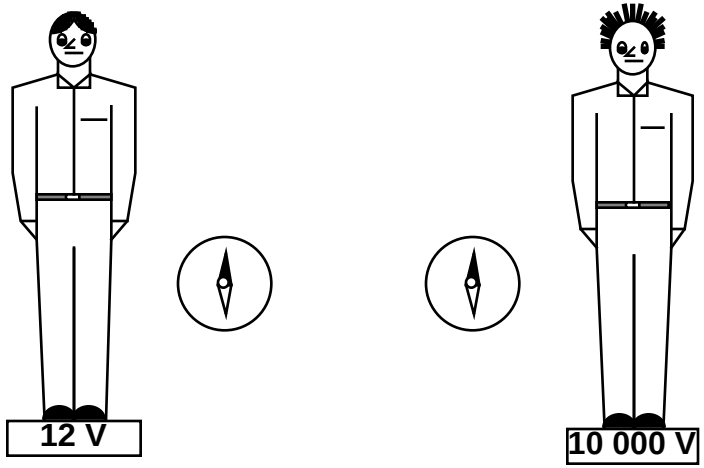
Electric charges create electric fields



- Fields radiate out in all directions, like spokes
- Fields decrease according to inverse square law
- Force visualized as "lines of flux" originating at positive charge and landing on negative charge
- Opposite charges attract; like charges repel
- Electric fields created by still or moving electric charges

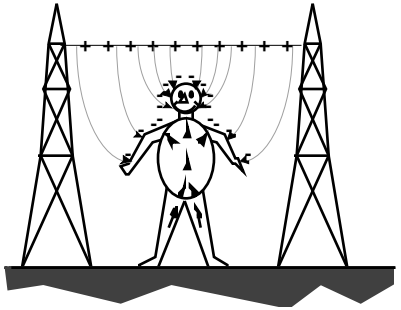
3

Electric fields are related to voltage



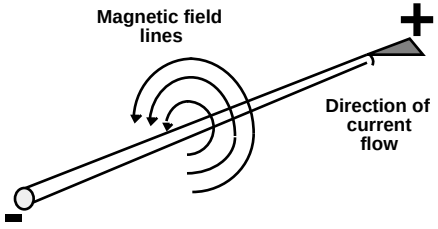
4 **The voltage creates an effect, but the compass needle doesn't move**

How do electric fields couple to the body?



- At this instant the overhead 60 Hz power line is positively charged.
- Opposite charges are accumulating on the surfaces of the person closest to the wire.
- They come from the ground through the ankles, feet, and trunk.
- At 1/120th of a second later, the line has a full negative charge which will push the negative charges back into the ground.
- The charges go back and forth like this like a piston going up and down in a cylinder.
- This model works at frequencies upto a few MHz

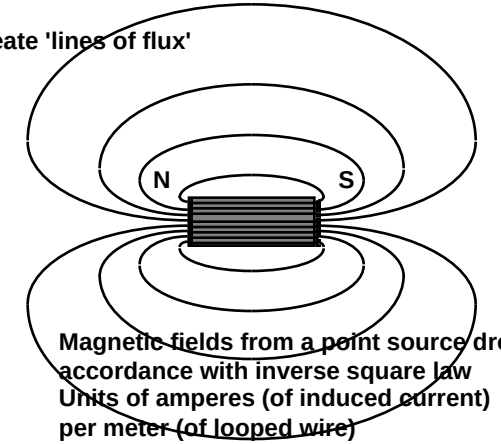
Moving electric charges create magnetic fields



- LEFT HAND RULE shown (Most of you learned this as "right hand rule" with current flowing from + to -. This depiction shows electrons flowing form - to +. Apologies to Ben Franklin!)
- Compass needle points in direction of yellow arrows

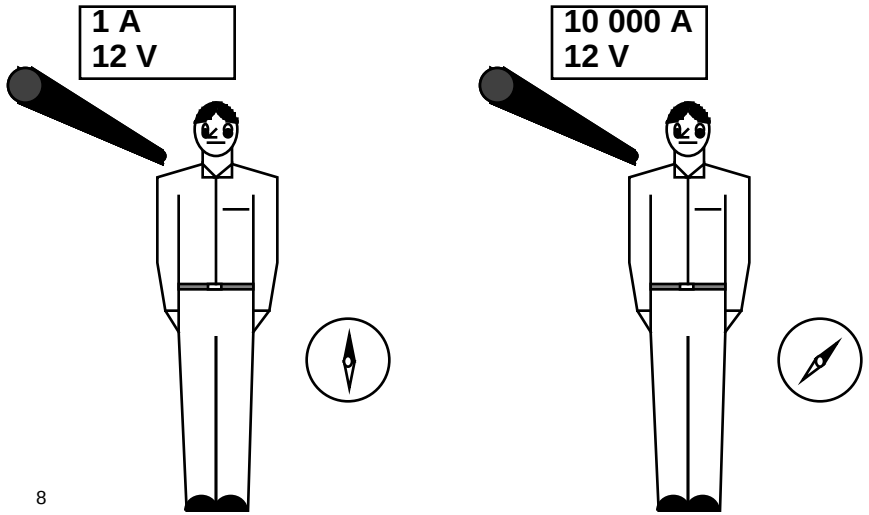
Remember high school physics about magnetic fields

Magnets create 'lines of flux'

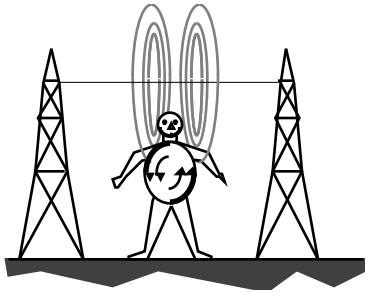


Magnetic fields from a point source drop off in accordance with inverse square law
Units of amperes (of induced current) per meter (of looped wire)
1 gauss = 80 A/m
1 tesla = 10 000 G

Magnetic fields are related to current



How do magnetic fields couple to the body?



The magnetic field causes charges to flow in conductive fluid (the persons tissue) in a direction perpendicular to the direction of the field as the field strength changes.
The currents are largest farthest away from the center of the object (the person's trunk in this example).

At 1/120th of a second later the direction of the magnetic field is fully reversed so the current will flow in the opposite direction

The current sloshes back and forth like water inside a washing machine during the wash cycle.

Current flow can also be induced in large organs, such as the brain or heart.

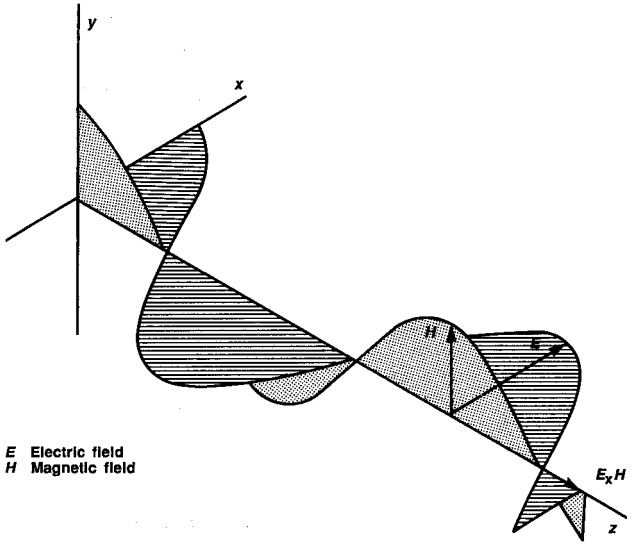
There are two fields in an electromagnetic wave (I)

- **The electric and magnetic fields are both perpendicular to the direction of travel.**
- **They travel together at very close to 300 million meters per second in air or vacuum (slower in water and tissue).**
- **The strengths of the electric and magnetic field change periodically.**
- **The number of complete changes in field strength and direction/polarity is the frequency given in units of hertz (one hertz = one full change of strength and polarity in a second; abbreviated Hz).**

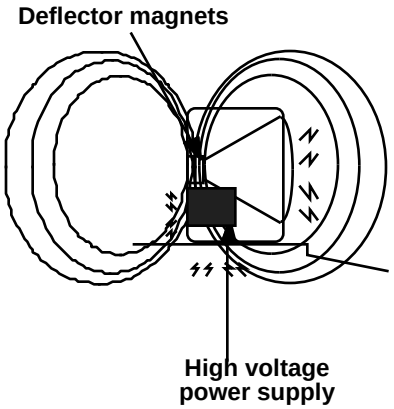
There are two fields in an electromagnetic wave (II)

- **The distance traveled during one full change of strength and polarity is the wavelength.**
- **Wavelength (in meters)= 300 million divided by the frequency (in Hz) and frequency = 300 million divided by the wavelength (in meters).**
- **This linkage of the two fields could be compared to marrying the two.**
- **REMEMBER: electric and magnetic fields can also exist separately too.**

There are two fields in an electromagnetic wave (II)

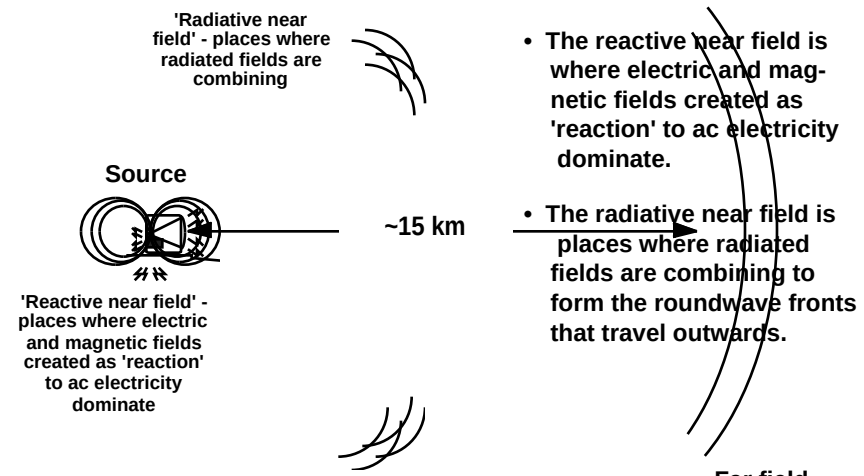


Near fields are found by energy sources (I)



- Near fields exist wherever there is electricity.
- A voltage will create an electric field.
- Current flow will create magnetic field.
- Electric and magnetic field can exist in different places.
- Electric field at any given place could be strong when the magnetic field is weak, and vice versa.
- These "near fields" drop off rapidly with distance.

Near fields are found by energy sources (II)



- The reactive near field is where electric and magnetic fields created as 'reaction' to ac electricity dominate.
- The radiative near field is places where radiated fields are combining to form the roundwave fronts that travel outwards.

Distance to 'far field' (radiation) ~ one wavelength

The far field is where *radiation* exists

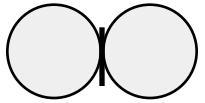
- **A strong electric field means a strong magnetic field, because the two are directly proportional to one another.**
- **Radiation obeys the inverse square law.**

Guidelines for near and far fields

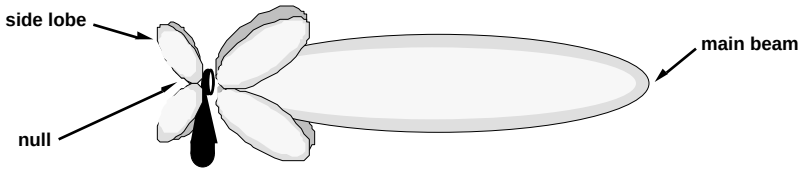
- **Near fields exist < 1 wavelength of source**
- **It is assumed near fields exist at frequencies below 300 MHz**
- **For aperture antennas: Distance to far field = 2*(major dimension or diameter of antenna)^2 /wavelength**

Radiofrequency/ microwave radiation & fields

Radiation from antennas has "nulls" and "lobes"



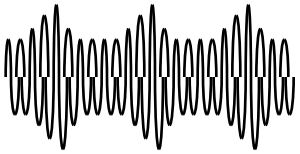
Pattern around a dipole



Pattern around a directional antenna
(dishes, horns, Yagis, etc.)

A brief reminder about AM and FM

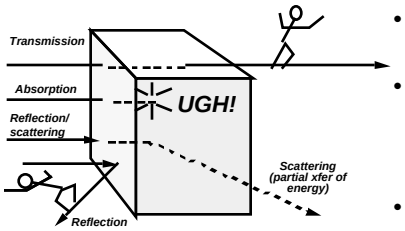
Amplitude modulation ("AM")



Frequency modulation ("FM")

- **AM = amplitude modulation**
  The strength of a higher frequency wave (810 kHz for KGO or 710 kHz for WABC) is changed (modulated) at a lower fre quency in AM broadcasting, the modulation frequency is the frequency of the announcer's voice or the music, the human range of hearing is just 20 Hz to 20 kHz
- **FM = frequency modulation**
  The frequency of a high frequency wave is changed at a lower frequency. In FM broadcasting, the higher frequency is the frequency of the station (say 101 MHz) and the lower frequency is the frequency of a voice or music.

There are four basic interactions between electromagnetic energy and matter



- **Transmission - No transfer of energy takes place with matter.**
- **Absorption - All energy is transferred to matter.**
- **Scattering - Some energy transfer occurs and longer wavelength radiation usually exits travelling in some different direction.**
- **Reflection - Electrical properties of what the radiation is coming from and what it is striking are so different that most of the radiation does not enterand bounces off. Mirrors and radar use this phenomenon; stealth technology tries to get around it.**

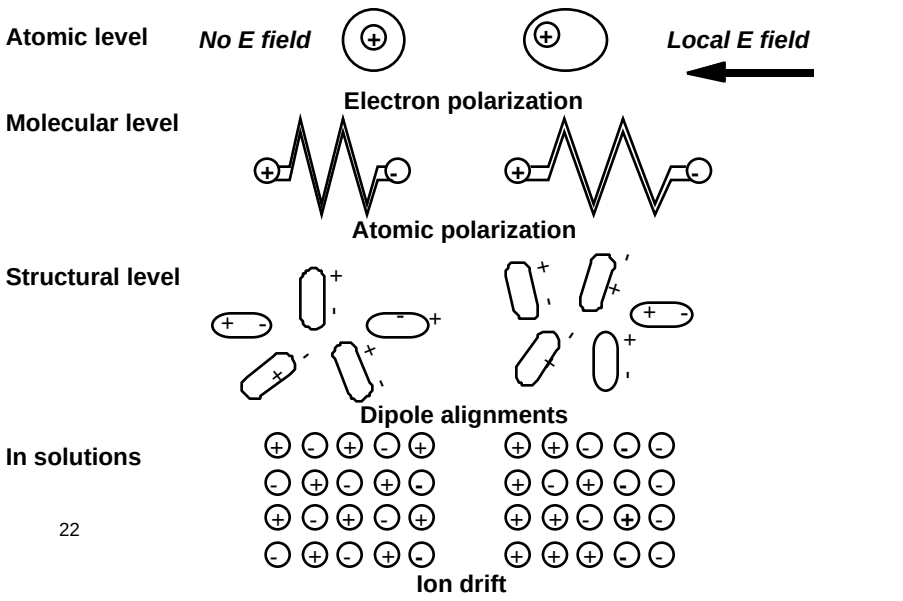
How does Rfmw transfer energy to tissue?

- **Electric field can create voltage that drives current flow**
- **Electric field can cause charged parts of molecules to vibrate**

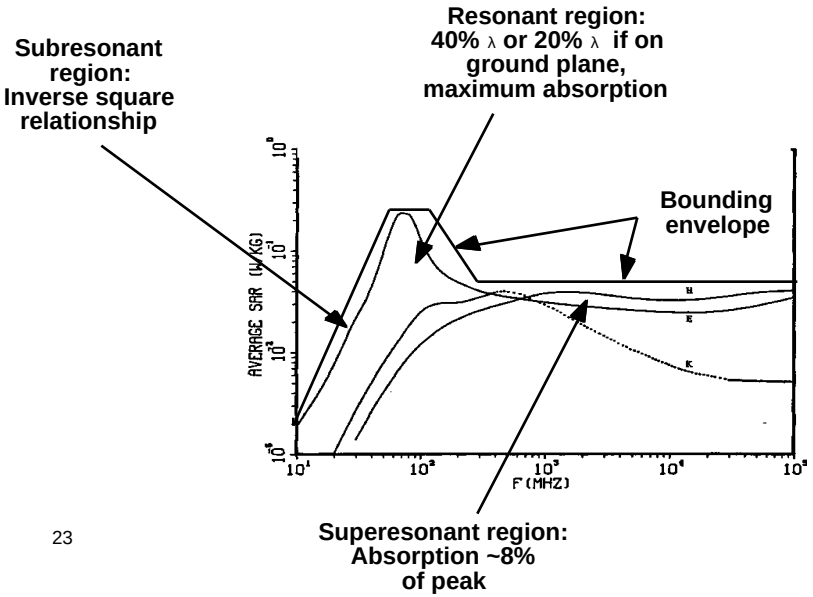
Energy transferred by both mechanisms finally appears as heat

- **Can involve water, ions in solution (Ca^{+2}, K^{+}, Na^{+}), proteins, or macromolecules (hydrated and unhydrated)**

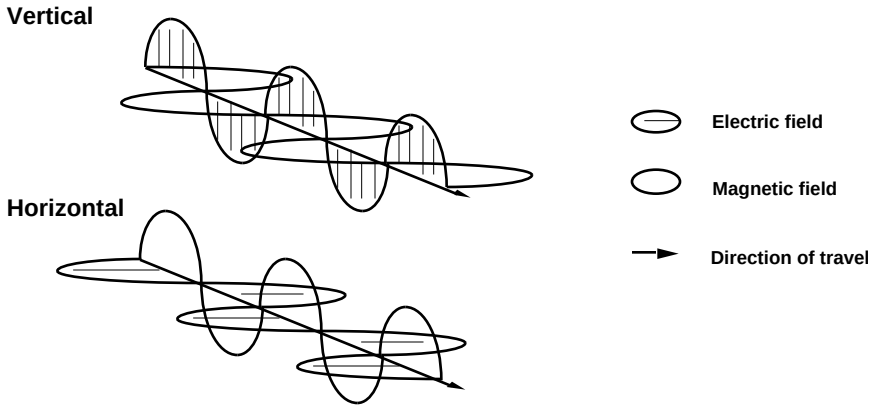
There are many ways to induce motion...



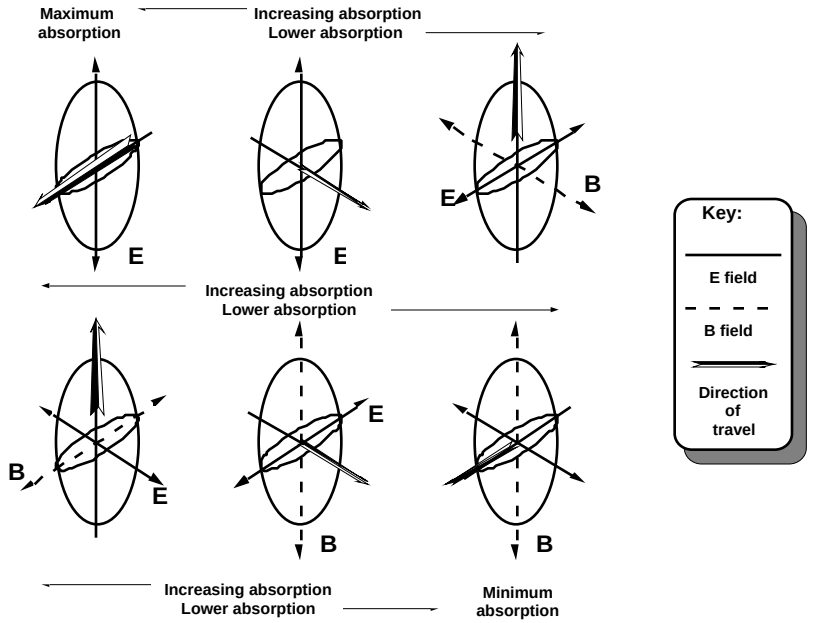
The size of an organism affects absorption



Polarization describes electric field's orientation relative to earth's surface



Polarization affects absorption (I)



Polarization affects absorption (II)

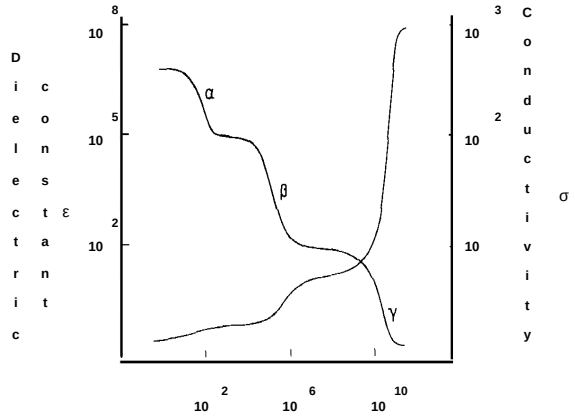
- **Max' absorption if electric field parallel to long axis of organism.**
- **Minimum absorption if the magnetic field is parallel to the long axis of the organism.**
- **This suggests magnetic field interacts weakly with tissue while electric field interacts strongly.**

The electrical properties of tissue vary with frequency

α **dispersion - Interaction with "counterions" outside cell. Cell contents shielded**

β **dispersion - Interaction with macromolecules. Intracellular fluid, but not organelles, affected.**

γ **dispersion - Water absorption occurs. All parts of cell affected.**



Rfmw dosimetry relates environmental exposures to biological effects (I):

- **Lingo for dose is 'Specific Absorption Rate' (SAR); units of W/kg of tissue mass**

- **Accounts for effects of:**
  - **Polarization**
  - **Size of organism vs. wavelength**
  - **Tissue electrical properties**

- **Techniques**
  - **Phantoms – improving with optical temperature probes**
  - **Irradiating carcasses followed by ir photography or calorimetry**
  - **Mathematical – improving due to supercomputers**
  - **Limited PC models available**

Rfmw dosimetry relates environmental exposures to biological effects (II):

Formally, SAR =

$$\frac{\sigma}{\rho} |E_i|^2$$

where:

σ = **Tissue conductivity (Siemens/m)**

ρ = **Tissue density**

E_i = **Peak internal electric field value (V/m)**

Western exposure criteria have similar dose rate objectives:

- ***All standards seek to limit whole body average dose rate to 0.4 W/kg***
- **20 W/kg allowed in extremities (hands, wrists, feet & ankles), 8 W/kg peaks allowed elsewhere by IEEE SCC 28**
- **NO extremity excursions allowed for eyes or testes in IEEE C95.1-1991**

A quick review of biological effects (I)

- **Eyes (*animals & humans*)**
  - **Cataracts – Animals can take hours at 120 mW/cm^2**
  - **Keratitis at 40 mW/cm^2**
- **Behavioral (*animals only*)**
  - **Various test changes ≥1.1 W/kg**
  - **Behavioral thermoregulation @ ≥1.1 W/kg**

- **~2/3 mW/cm^2 associated with perceptible warmth in humans**
- **Endocrine (*animals only*)**
  - **Corticosteroid increase @ 4.1 W/kg**
  - **Thyroid increase @ 8.3 W/kg**
-

A quick review of biological effects (II)

- **Immune (*animals only*) – T lymphocyte activity alteration @ ≥1.4 W/kg**
- **Blood – no consistent results**
- **Cancer – No specific animal life span study seeking cancer has been done; epi' studies of radio hams, electrical workers, and physical therapists found excess cancer, but other studies have not found association**

A quick review of biological effects (III)

- **Neurological (*animals only*) – Tests of blood/brain barrier contradictory; *unreplicated* studies with AM & PM fields show brain metabolism changes @ >0.02 W/kg 200 & 591 MHz, but not @ 2450 MHz**
- **Mutations – Mutations not found in replicated studies to date**
- **Reproduction – (*animals only*)**
  - **Temporary male sterility @ 5.6 W/kg**
  - **Testicular changes @ ≥15 W/kg**
  - **Leutenizing hormone changes @ >2 W/kg**

- **Teratology (*animals only*) – Malformed offspring found @ ≥31 W/kg, strong thermal dependance (temp >41°C)**
- **Thermoacoustic – (*Pulsed* only)**
  - **Observed in radar operators in WWII as perceived clicking sound**
  - **Possible cause of neurological effects observed by James Lai @ 0.6 W/kg.**

Radiofrequency (< 300 MHz) limits are based on electrical current flows

Two scenarios:

Rf induces voltage in grounded person acting as aconductor

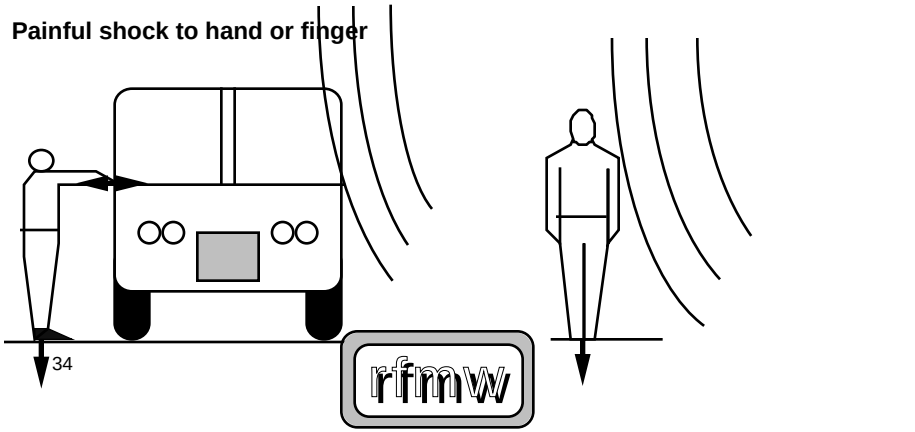
Person acts as current path to ground by touching charged conductor

Painful shock to hand or finger

Rf induces current flow in person

Current flows to ground

High local dose rates (SARs) in ankles



Rfmw standards are based on frequency ranges and resonance

- ***Subresonant*** **(<3 MHz) – Body and parts do not function as good antennas. Current flow considerations dominant throughout**
- ***Resonant*** **(3 MHz - 6 GHz) – Body becomes good antenna which maximizes absorption.**
  - **Current flow and SAR (dose) both important considerations (current flow ≤100 MHz). Absorption falls of in proportion to square of frequency from 3 - 30 MHz.**
  - **Standards most stringent from 30 - 300 MHz.**
  - **In transition to next region (from 300 MHz - 3 GHz) absorption drops off linearly as frequency increases.**
- ***Superesonant*** **(6 GHz - 300 GHz) – Body no longer acts as good antenna, absorption at ~1/10 peak absorption. Quasi-optical focusing from 6 - 15 GHz. Skin absorption dominant >15 GHz (penetration <1 cm).**

What are standards setting groups doing?

- **IRPA/ICNIRP guidelines in 1984 & 1988**
- **IEEE SCC 28 (ex ANSI C95 committee) adopted standard in 1991, adopted by ANSI in 1992**
  - **Treats magnetic fields more leniently**
  - ***Sets rf current flow limits***
  - **Sets public exposure limits**
  - **Next revision in preliminary literature review stage**
- **The OSHA standard 'on the books' is archaic 10 mW/cm^2 standard from 1966!**

  But...
- **OSHA *can* enforce C95.1-1991 through Brock UAW v General Dynamics Land Systems Division ruling that allows OSHA to enforce state-of-the-art standards through General Duty Clause of the OSHAct**

Late breaking developments

- **CENELEC active, Finns taking lead on pulsed fields**
- **IEEE beginning to address issue of product stewardship as a result of cellular phone law suits**

Occupational (controlled access) field strength limits for rfmw

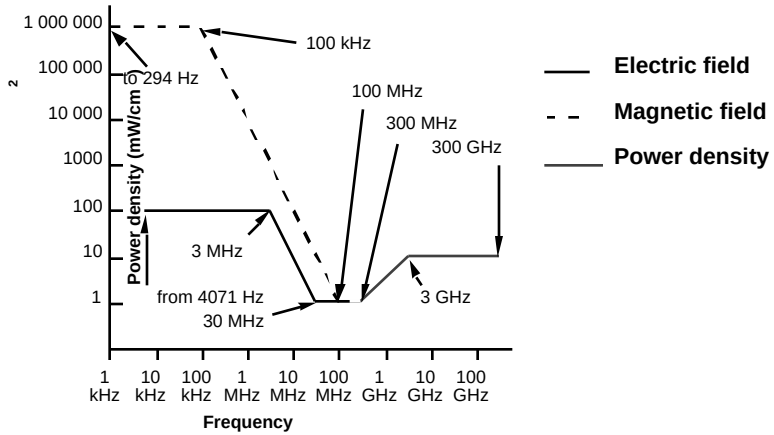
The exposure values in terms of electric and magnetic field strength are the values obtained by spatially averaging values over an area equivalent to the vertical cross-section of the human body (projected area).

f = Frequency in MHz

Frequency Range (MHz)	E (V/m)	H (A/m)	Power Density, S (mW/cm^2)	Averaging Time (minutes)
			E , H	E , H or S
0.000294 - 0.1	—	163	(100, 1,000,000)	[a] 6
0.004071 - 0.1	614	—	(100, 1,000,000)	[a] 6
0.1 - 3.0	614	16.3/f	(100, 10,000/f2)	[a] 6
3 - 30	1842/f	16.3/f	(900/f2, 10,000/f2)	[a] 6
30 -100	61.4	16.3/f	(1.0, 10,000/f2)	[a] 6
100 - 300	61.4	0.163	1.0	6
300 -3,000			f/300	6
3,000 - 15,000			10	6
15,000 -300,000			10	$616{,}000/f^{1.2}$

[a] These plane-wave equivalent power density values, although not appropriate for near-field conditions, are commonly used as a convenient comparison with MPEs at higher frequency and are displayed on some instruments in use.

Occupational (controlled access) field strength limits



- **This is the mirror image of the absorption curve!**
- **Strictest limits from 30 MHz to 300 MHz**
- **See Table A2 of Supplement 26.12 for specific figures.**

Concerning the fetus...

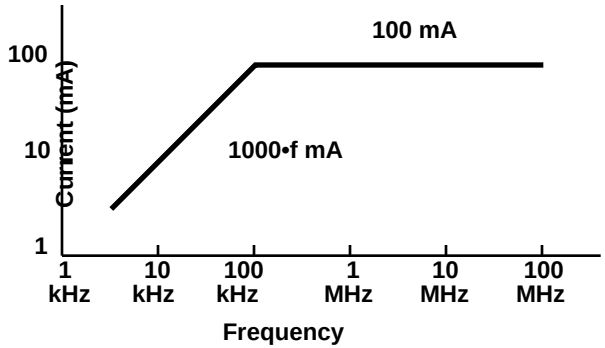
- **The fetus is regarded as a member of the general public**
- **Uncontrolled access criteria apply**

Occupational current flow limits (controlled access locations)

Part B - Induced and Contact Radiofrequency Currents

Frequency range (MHz)	Maximum Current (mA) Through both feet	Through each foot	Contact
0.003 - 0.1	2000f [a]	1000f [a]	1000f [a]
0.1 - 100	200	100	100

[a] "f" is frequency in units of MHz.



General public (uncontrolled access) field strength limits

- **General public exposure criteria are typically 1/5 occupational criteria, but can last 5 times longer**
- **Equal to occupational criteria at lower frequencies**
- **See Table A3 of Supplement 26.12 for specific figures**
- **Current flow limits also set**

Relaxations For Partial Body Exposures

	Frequency in GHz	Peak Value of Mean Squared Fields [a]	Equivalent Power Density in mW/cm^2
Occupational Exposures	$0.001 \le f < 0.3$	$< 20\ \bar{E}^2$ or $20\ \bar{H}^{2}$ [b]	
	$0.3 < f \le 6$		< 20
	$6 < f \le 96$		$<20\ (f/6)^{1/4}$ [d]
	$96 < f \le 300$		40
Public Exposures	$0.0001 \le f \le 0.3$	$< 20\ \bar{E}^2$ or $20\ \bar{H}^2$ [c]	
	$0.3 < f \le 6$		4
	$6 < f \le 30$		$f/1.5$ [d]
	$30 < \le 300$		20

[a] These relaxations *do not* apply to the locations of the eyes and the teste

[b] $\bar{E}$ and $\bar{H}$ are the spatially averaged values from Table 2.

[c] $\bar{E}$ and $\bar{H}$ are the spatially averaged values from Table 3.

[d] f in GHz.

- **Spatial exposures allowed for most parts of body so long as spatial average complies with exposure criteria.**
- **No exception for the locations of the eyes or testes!**
- **Frequency dependent, but often 20 X average in terms of power density or field strength squared**
- **See Table A4 of Supplement 26.12 for specific figures.**

Rfmw industrial exposure standards are typically based on 6 min. time intervals

- **Excursions allowed if 6 min average is within limits**
- **30 min intervals used for public exposure standards**
- **Different from chemical exposure standards where excursions above an eight hr average limit are allowed**
- **This averaging time idea becomes strained for pulses - do we allow a million times the six minute exposure limit for a pulse lasting one millionth of six minutes?**

IEEE gives guidance about pulsed rfmw...

Pulsed limit = $\frac{\text{IEEE cw limit x IEEE averaging time (in secs)}}{\text{5 x pulse duration (in secs)}}$

Peak E field <100 kV/m

Cw limits apply to situations in which there are more than five pulses during the averaging time

Are you FCC regulated (I)?

- **Affects**
  - **Broadcasting**
  - **Technologies that radiate into the airwaves; that could mean YOU**
- **FCC promulgated broadcast safety regs on August 1, 1996**
- **These rules establish worker and general public exposure standards**
- **IEEE C95.1-1991 was largely unused reflecting doubts held by some about composition of C95 committees**
- **Older C95.1-1982 standard and NCRP general public guidelines adopted instead; C95.1-1991 current flow standards adopted**
- **Not directly applicable to DOE facilities, but it could become obligatory in the future**
- **SAFETY EVALUATIONS (surveys) REQUIRED**
- **Please see the following showing FCCs occupational (controlled access) and uncontrolled (general public) exposure criteria**
- **Contact the Nonionizing Radiation safety Officer, 38036, if you need a copy of the FCC regs**

Are you FCC regulated (II)?

Limits for Occupational/Controlled Exposure

Frequency Range (MHz)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (mW/cm2)	Averaging Time (minutes)
0.3-3.0	614	1.63	(100)*	6
3.0-30	1842/f	4.89/f	(900/f2)*	6
30-300	61.4	0.163	1.0	6
300-1500	--	--	f/300	6
1500-100,000	--	--	5	6

f = frequency in MHz

* = Plane-wave equivalent power density

NOTE 1 TO TABLE 1: Occupational/controlled limits apply in situations in which persons are exposed as a consequence of their employment provided those persons are fully aware of the potential for exposure and can exercise control over their exposure. Limits for occupational/controlled exposure also apply in situations when an individual is transient through a location where occupational/controlled limits apply provided he or she is made aware of the potential for exposure.

Are you FCC regulated (III)?

Limits for General Population/Uncontrolled Exposure

Frequency Range (MHz)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (mW/cm2)	Averaging Time (minutes)
0.3-1.34	614	1.63	(100)*	30
1.34-30	824/f	2.19/f	(180/f2)*	30
30-300	27.5	0.073	0.2	30
300-1500	--	--	f/1500	30
1500-100,000	--	--	1.0	30

f = frequency in MHz

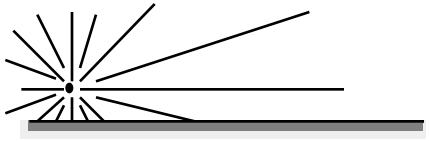
* = Plane-wave equivalent power density

NOTE 2 TO TABLE 1: General population/uncontrolled exposures apply in situations in which the general public may be exposed, or in which persons that are exposed as a consequence of their employment may not be fully aware of the potential for exposure or can not exercise control over their exposure.

The basics of rfmw protection are familiar

- **Shielding**
  - **Metal screen (1/4 λ) – good bonding critical**
  - **RAM – Ecosorb carbon impregnated foam**
  - **Enclosure – Grounded metal case, coax cables, waveguides**

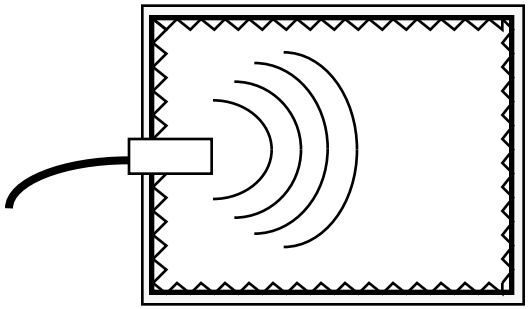
- **Time – often ineffective due to six minute averaging time interval (*not* 8 hrs. or 15 mins!)**



- **Distance – often highly effective for fields and radiation, and especially magnetic fields**

Using shielding for protection

- **Shielding**
  - **'Ecosorb' carbon impregnated foam**
  - **Metal conducting enclosures**



Don't stare into open waveguides!

- **It's like looking down a gun barrel or into a laser beam**

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This is the rfmw warning symbol

- **The “radiator”. AKA the angel or the lighthouse**
- **Out since 1982**
- **Replaces 1966 red, black and aluminum diamond shown in OSHA reg**
- **OSHA agreed to permit new sign to be used in 1991 making diamond obsolete**

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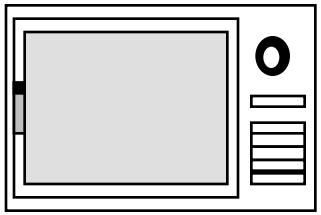
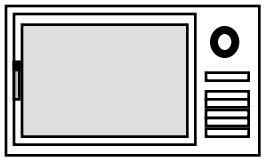
Microwave ovens are covered by different regulations

- New ovens must leak <1 mW/cm^2 5 cm from any surface
- Old ovens can leak <5 mW/cm^2 5 cm from any surface
- Per 21CFR 1030.10



The threat of microwave ovens to pacemakers is over rated!

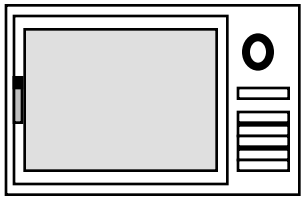
- Ovens have 'stirrers' ('rotating waveguides') to spread energy evenly around the cooking chamber
  - Stirrer modulates whatever leaks from oven
  - Modulation has a frequency in range of heart beat
  - Pacer can pick up modulation and respond to it as though it was heart beat
- Pacemakers now tested against electric field equivalent to 10 mW/cm^2
  - Leakage standard for old ovens is 5 mW/cm^2
  - Special warning signs not needed except (maybe) close to intensively used ovens



Users should check ovens

- **Annual leakage surveys not warranted**

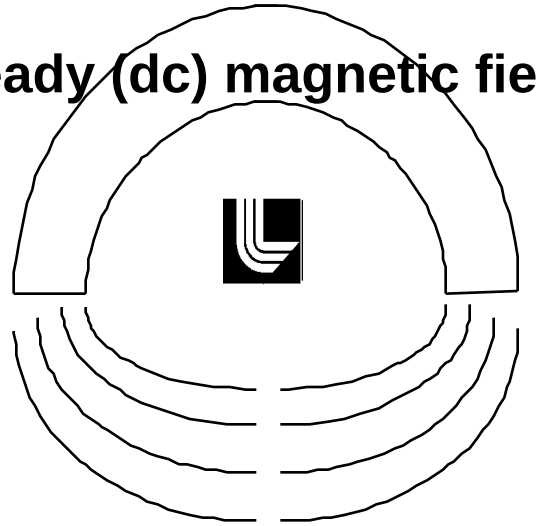
- **Users should check for damage to:**
  - **Window**
  - **Door**
  - **Door jamb**
  - **Cooking chamber**
  - **Interlock**



Recapping rfmw

- **Rfmw consists of electric and magnetic fields which are rigidly connected in far field radiation, otherwise the fields can exist separately (existance of separate fields assumed for**
- **.Rfmw energy transferred to tissue finally appears as heat**
- **.Rfmw dosimetry important to setting standards, general objective is SAR (dose rate) of 0.4 W/kg as whole body average**
- **Adverse rfmw effects known in humans limited to eye cataracts, skin burns, and electric shocks**
- **Microwave oven users should check condition of window, door, door jamb, and cooking chamber**
- **Protect yourself: Don't stare into open waveguides!**

Steady (dc) magnetic fields



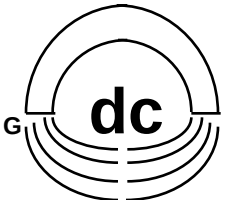
What are the biological effects of static magnetic fields?

- People become nauseous, develop taste in mouth, vertigo, and magnetophosphenes (flickering sensation in the eyes) @ 4 T
- Voltage generated by flow of charged fluid (blood) in large vessel (aorta) in magnetic field can induce current flow of 100 mA/m (10% of endogenous level) @ 5 T (calculated at high cardiac output, aortic blood velocity =60 cm/sec)
- Pacemakers can malfunction @ at 3.1 G (this is from a German report for an unspecified model of pacemaker, most pacemakers take higher fields to malfunction)
- Aneurysm clip twisted off of test animals artery @ 2.2 kG (210 G/m field gradient)
- Circadian rhythms affected by merely rotating Earth's 1/2 G dc field!

dc

The exposure standards for static magnetic fields are...

- 2000 G as an 8 hr TWA, 2 T as a peak
- 400 G for the general public exposure limit
- Pacemaker warnings at 5 G
- Precautions for users of metallic prostheses at 30 G
- Precautions for metal tools at 30 G



- Overexposures unlikely, but fields which could be hazardous to pacemaker users or cause problems for prostheses and tool users are much more likely to be found.

Interational Commission on Non-Ionizing Radiation Protection. "Guidelines on Limits of Exposure to Static Magnetic Fields". Health Physics 66: 100-106 (1994).

A word about pacemakers and medical electronic implants

- Pacemakers work by amplifying the heart's natural electrical activity which has a variable frequency and the features well known in EKGs
- Pacemakers tested using a permanent magnet held over chest in cardiologist's office or in user's home telemetering to cardiologist
- Test causes pacemaker to fire at fixed rate
- This could occur in uncontrolled location due to magnetic fields
- Mode change could threaten a small percentage of pacemaker users
- Some other electronic implants also susceptible (for example, electronically controlled bladder valves)
- Check for people with medical electronic and medical implants!
- Health Services has an extensive list of articles that can be hazardous in strong magnetic fields - this is included in your handouts

A gauss meter survey is not enough to locate attractive force hazards

- **To hunt for where strong attractive forces exist:**
  - **Locate areas where fields >30 G by gauss meter**
  - **Then use a tied-paper clip, or equivalent, survey to locate where tool hazards actually exist**
  - **Tie a string around string of common soft steel paper clips and use it to fish for places where magnetic attraction forces are strong**
  - **Post approaches to areas where the tied-paper clip survey shows strong attractive forces exist**

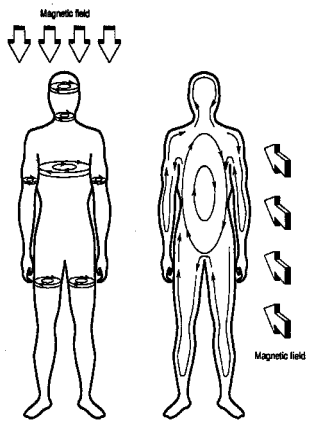
Magnetic attraction can be hazardous!

- **Attractive force proportional to field strength and field gradient (how rapidly the field strength changes over distance) so a simple gaussmeter survey is not enough**
- **Attractive force hazardous for:**
  - **Tools & compressed gas cylinders**
  - **Prosthetic implants made of magnetizable materials (this can include machined stainless steel and 340 series stainless steel alloys**
  - **Jewelry and some watches**

- **Credit cards & badges (beginning at ~10 G)**

Guidelines have been proposed for pulsed magnetic fields

Orientation	Body part affected	dB/dt (T/sec)
Head-toe	Front of heart	71.3
"	Peripheral nerves above sternum	62.6
Front-back (torso only)	Side of heart	72.1
	Peripheral nerves at side of rib cage	38.8
Side-side (torso only)	Front of heart	50.8
	Peripheral nerves above stomach	43.1
Side-side (whole body exposure)	Front of heart	45.9
	Peripheral nerves above stomach	37.8



Originally developed for MRI patients based on induced eddy currents, no safety margin. With a safety margin of ~7, the limit would be205 T/s.
IEEE will set limit at 20 T/sec for pulses >200 µsec, higher for shorter pulses.

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Recapping Static Magnetic Fields

- **Exposure limit is 2000 G**
  - **Nausea, symptoms @ 4T**
  - **Generates voltage in blood**
  - **Circadian rhythm disruption @ 1/2 G**
- **Special medical considerations:**
  - **Pacemaker users keep out >5 G**
  - **Have users of other prostheses checked before entering areas where field >30 G**
- **Tool controls begin @ 30 G**
  - **Use a tied-paper clip, or equivalent, survey to locate where tool hazards actually exist and post these areas**

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LLNL handles non-ionizing radiation as part of its HAZCOM effort

- **Non-ionizing radiation (NIR) covered by Supplement 26.12 of the *LLNL Health & Safety Manual* of November 1995**
- **The standards just discussed are listed along with others to address subradiofrquency fields**
- **NIR is handled just like chemicals:**
  - **Inventory sources (use door sign)**
  - **HC evaluates exposure**
  - **Controls based on results of evaluation**
- **NO new forms, NO new paperwork**
- **Contact your ES&H Team for assistance; the building IH will handle your inquiry**

Reviewing Supplement 26.12

- **See section 4.1 for controls**
- **See section 4.2.1 for inventory guidance**
- **See section 3 and Appendices A1 through A4 for guidance about permissible exposure criteria**
- **See section 4.1 and Appendix A5 for sign posting guidance**

Physical agents need to be inventoried (I)

- **Steady (dc) magnets that could generate fields >5 G in occupiable places**
- **Equipment which can create 60 Hz electric fields >1 kV/m or magnetic fields >1 G in occupiable areas (>2.5 kV & unshielded or >100 A)**
- **All permanently installed rf gear capable of radiating over 1 W into an open area at frequencies between 3 kHz and 300 GHz or of emitting over 100 W if the output is normally completely enclosed by coaxial cables, waveguides, or dummy or real loads**
- **All satellite and permanently installed communications transmitters (receivers do not need to be listed)**
- **'Walkie-talkie' portable communications sets capable of radiating >7 W at frequencies between 100 kHz and 450 MHz or >7 X (450/f) W at frequencies between 450 MHz and 1.5 GHz (f is the frequency in MHz units)**
- **All induction heaters**
- **Building main power supply rooms**

***SURVEYS* are in order for these sources!! Call your Team IH for support.**

Physical agents need to be inventoried (II)

- **Class 2, 3a, 3b, and 4 lasers. Disposable semiconductor lasers do not need to be listed individually; the inventory needs to list the manufacturer, model number and number of disposable lasers on hand**

  Special surveys of laser installations aren't needed because they're already covered per Ch. 28 of the H&S Manual. Your IS rep' covers laser safety issues. But the following need to be evaluated:

- **Infra red sources rated >10 W (IS)**
- **Arc lamps (IS)**
- **Ultra violet sources rated >1 W, including mercury lamps not used for lighting (IS)**
- **Noise sources creating sound levels >85 dBA (IH)**

  Consumer appliances don't need to beinventoried! You <u>don't</u> need to list every light bulb and microwave oven!